Review of the doctoral dissertation of Magdalena Peciak, M.Sc., Eng., "*Application of Model Based System Engineering (MBSE) methods in designing hybrid and electric propulsion systems for aircraft.*"

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The review was prepared in accordance with the requirements of Article 187 of the Act of July 20, 2018, "Law on Higher Education and Science."

The presented dissertation is a scientific monograph written in English and consists of the following parts:

1 Introduction
2 Design process of aircraft with new propulsion system
3 Parametrised models of the subsystems
4 Analysis and modelling of the alternative propulsion systems
5 Alternative propulsion system arrangement
6 Conceptual design of a hydrogen fuel cell aircraft
7 Conclusion
Bibliography
Appendix

The introduction, constituting the first chapter of the thesis, defines the purpose of the thesis and presents a review of the relevant literature. The thesis aimed to adapt the traditional design process, which utilizes historical data and is applied for conventionally powered aircraft, to the design of aircraft with alternative propulsion systems, for which available historical data is insufficient. To achieve this goal, multi-domain modeling was proposed, which takes advantage of parameterized models of aircraft components, hypothesizing that such an approach could eliminate the need for historical data. The adaptation work was narrowed to the initial design stage, i.e., the conceptual project. Based on the literature examination, the design processes and the alternative propulsion systems most suitable for aviation applications were characterized. The chapter ends with presenting the organisation of the thesis.

Chapter 2 analyzes the relationships between the requirements for the designed aircraft, the forces acting in flight, and the aircraft's systems. Based on these considerations, an adaptation of the current design process was proposed to address the specific needs of alternative propulsion systems that could be used in aviation.

Chapter 3 categorized the subsystems relevant to airplanes of general aviation (GA) and analyzed their components based on functions. Based on these considerations, appropriate parametric models of the subsystems were selected from the

Matlab/Simulink library, taking into account the design parameters. This formed the basis for developing powerplant models that could be used in subsequent stages of the design process.

In Chapter 4, based on the partitive parameterized subsystem models generated earlier, models describing the entire propulsion systems were developed using Matlab/Simulink. These models allowed for the estimation of their mission-specific performance. It was achieved by linking the propulsion system models with the parametric airframe model and the mission-dependent environmental parameters.

Chapter 5 focuses on the feasibility of analyzing the impact of alternative propulsion systems on airframe geometry and mass distribution, using OpenVSP to develop a parameterized aircraft model. Such a model allows for simplified initial estimation of the airframe's aerodynamic characteristics. This model and the alternative propulsion system model are coupled through an iterative loop, resulting from the considerations in Chapter 2

Chapter 6 presents an example application of the design method discussed in the previous chapters to a GA aircraft with a hydrogen fuel cell propulsion system. The commercially available components of such a propulsion assembly were selected based on the simulated performance of the airframe with a pre-defined geometry and a propulsion system with parameters determined based on this geometry and the aircraft's mission. Taking into account the parameters of the selected, commercially available components, the airframe geometry was modified, and the airplane's performance was verified. Finally, the obtained results were presented in the form of sketches showing the airframe geometry and the arrangement of the propulsion system components within it.

The above meets the requirements of p. 3 Art. 187 of the Act.

The thesis was written in a foreign language and contained the required abstract in Polish. The above meets the requirements of Article 187, Section 4 of the Act.

Reviewing the content of Parts 2-6 and the cited literature, as well as the absence of any information regarding plagiarism, allows the reviewer to conclude that the submitted thesis demonstrates the candidate's general theoretical knowledge in the field of Mechanical Engineering and the ability to conduct independent research.
The above meets the requirements of Article 187, Section 1 of the Act.

Experience concerning the application of alternative propulsion systems in aviation is still limited. Therefore, in this case, applying the trend tracking method, traditionally employed in conceptual aircraft design, is difficult. An alternative approach was presented by the PhD student, consisting in taking advantage of the MBSD tool. For this purpose, using this tool, the student developed parameterized models of the most promising alternative propulsion systems, i.e., all-electric, parallel, and serial hybrid electric-combustion systems, and a hydrogen fuel cell-battery-assisted system, using

MATLAB. As an example illustrating the applicability of the proposed approach, a conceptual design of a GA aircraft was developed, with a propulsion system consisting of hydrogen fuel cells supported by batteries. According to the reviewer, the above meets the requirements of Section 2 of Article 187.

Considering all the above, I request that the PhD thesis be admitted to defense.

However, the thesis contains several controversial statements and information that is too general. It requires additional explanations, which should be part of the thesis's defense.

1. The following terms may be a source of confusion: "*historical data*", "*classic design process*", and "*model-based design process for aircraft with alternative propulsion systems*". Please clarify their meaning in the context of the presented thesis and highlight the differences between the latter two.

2. The thesis contains two workflow diagrams: "*Conventional Aircraft Design Process*" shown in Figure 2.4, and "*Proposed Adaptation of the Aircraft Design Process to Alternative Propulsion*" shown in Figure 2.5. Please, (a) indicate any significant differences between them in the context of the thesis, (b) explain the physical data flow diagrams regarding the design phases: "Requirements Phase," "Conceptual Design Phase," "Preliminary Design Phase," "Detailed Design Phase," and "Prototype Construction and Testing", i.e., what data (parameters) are input and what are expected output data (parameters) in the design phases "Requirements Phase," "Conceptual Design Phase," "Preliminary Design Phase," "Detailed Design Phase," and "Prototype Construction and Testing"; (c) justify the absence of iterative loops and aircraft stability analysis. Is the absence of iterative loops merely an error, since their use was indicated in Chapter 6, which contains an example of an alternative design process?

3. How does the pilot interact with the propulsion unit? Is it through the "Power Electronics" module, shown in Figures 4.1-4.4?

4. As before, I would appreciate physical data flow diagrams regarding models in Figures 4.5 and 4.7-4.10.

6. Please comment on the results of applying your proposed design process, presented in Chapter 6. In particular, I would appreciate your commentaries on the expected limits of the aircraft's center of gravity (gravity center envelop), crew and passenger location, flight stability, including directional stability, landing gear configuration and anticipated space in the fuselage allowing its retractability, anticipated fuselage cutouts and their consequences, battery selection with consideration of the allowed temperature service range, thermal management (cooling/heating of the propulsion system components, maintaining cabin temperature), and takeoff profile (climb rate after take off).

Prof. P. Czarnecki

/podpis odręczny/

*wyłączenie jawności w zakresie danych osobowych oraz ochrony prywatności osoby fizycznej na podstawie art. 5 ust. 2 ustawy z dnia 6 września 2001 r. o dostępie do informacji publicznej (tj. Dz.U. z 2016 r., poz. 1764)